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# Technical Note 1966-64

# Observations of Inner and Outer Zone Electrons Since December 1965

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
LINCOLN LABORATORY

# OBSERVATIONS OF INNER AND OUTER ZONE ELECTRONS SINCE DECEMBER 1965

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*Group 63*

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LEXINGTON MASSACHUSETTS

## ABSTRACT

A Silicon Surface Barrier Detector Electron Telescope measuring Integral and Differential Electron Energy Spectra over the range of 130 KEV to 4.5 MEV was placed into orbit in late 1965. The initial orbit had an inclination of 26.6$^{\circ}$, apogee of 33,600 KM, perigee of 200 KM, and a mean orbital period of 589.6 minutes.

The data from the experiment are presented in terms of single orbit passes on selected days showing outer zone maxima in omnidirectional flux intensity for 130 KEV, 700 KEV, and 2.5 MEV integral Spectra in the region near L=4, and a minimum near L=3.5 which characterizes the slot between the inner and outer zones. Diurnal variations are characterized by flux changes which show marked correlation with $K_p$ index at L=6. The degree of correlation decreases with decreasing L value. Spectral steepening is seen to occur during periods of increased geomagnetic activity. The diurnal flux changes also exhibit energy vs. time dependencies with the higher energy electron fluxes generally reaching their maximum later in time.

Accepted for the Air Force
Franklin C. Hudson
Chief, Lincoln Laboratory Office

# OBSERVATIONS OF INNER AND OUTER ZONE ELECTRONS SINCE DECEMBER 1965

A solid-state electron telescope experiment was carried aboard a satellite launched in the last quarter of 1965. Though planned as a quasi-synchronous equatorial satellite its initial orbit had an inclination of 26.6$^{\circ}$, apogee of 33,600 km, perigee of 200 km and a mean orbital period of 589.6 minutes.

The instrument aboard this satellite is shown in Figure 1. The collimator has been removed displaying the entrance aperture. The collimator provides a 10$^{\circ}$ acceptance cone for particles. The remainder of the detector array is shielded by approximately 3.4 g/cm$^2$ of aluminum. Figure 2 has the electronics box open so that leads from detectors, biasing networks and individually shielded preamps are shown.

The detector array consists of a stack of five 500 micron thick silicon surface barrier detectors with abosrbers. The signals from the detectors are fed to charge sensitive amplifiers. The pulses from the amplifiers trigger tunnel diode discriminators which in turn send signals to the coincidence logic. A block diagram of the experiment is shown in Figure 3. The coincidence logic produces several modes of measurements including differential, integral, and bremstrahlung. The control logic cycles through the various modes, each of which provide a measure of the directional flux of particles in prescribed energy ranges. There are two counters, one of which is used in a hybrid fashion, the other used linearly. The hybrid counter operates in a linear mode until it reaches 32 counts whereupon it switches to counting an oscillator for the remaining acceptance time of the measurement. In effect then, over one range, it measures the number of counts accumulated in a fixed time and when this range is reached it measures the time in which a fixed count is accumulated, thereby providing a large dynamic range for a small number of data bits. On board calibration replaces the real pulses from the detectors with the output of a sliding pulser for a part of the cycle thereby checking the operation of each channel.

The data from the experiment are transmitted via a telemetry link in digital form and recorded on magnetic tape at oneof two ground terminals. The data are then processed by a digital computer. Figure 4 shows a computer printout of 2 modes of raw data. It contains approximately 22 minutes of unprocessed data. For these raw data records the ordinate is not linear with count rate because of the properties of the hybrid counter.

The lower curve shows counts from the first detector which has its discriminator set at 130 Kev and gives a good representation of the integral spectra above this threshold. The "not $I_p$" indicates that the energy deposited in the first detector did not exceed 1 Mev. Since the active depth of the detector is 500 microns most of those counts which would normally result from energetic protons are excluded. One mode consists of a measure of this energetic proton flux while all other modes have this anticoincidence feature. The upper curve is the mode in which a coincidence is required between pulses from the first and second detector. The effective threshold of this mode is 700 Kev. Bremstrahlung is eliminated from this measurement by this coincidence technique. Roll modulation is apparent here. The period between individual measurements is 5.2 seconds. The satellite spin period here is 5.8 seconds which gives a beat period of approximately 5.0 seconds. Sampling different portions of the particle pitch angle distribution then gives rise to a modulation of the data with the period of the beat.

Figure 5 is a plot of averages of several modes taken during a single period for which the satellite was visible to the ground site. The averages represent 22 minute intervals of data. The progress of the satellite for this data pass is outbound from approximately L = 2 to apogee at the broad minimum where L = 6.5 then inbound for the remainder of the curve. The two maxima occuring at approximately L = 4 represent the peak particle distribution in the outer Van Allen belt. The top curve is an integral measurement with $E > 130$ Kev. The other curves show counting rates above energy thresholds of 700 Kev and 2.5 Mev and a proton flux count.

In Figure 5 the general shape of the curves shown are typical of those obtained for most of the data passes of the instrument. A day which shows atypical behavior of the data is presented in Figure 6. This data was taken during an outbound pass of the satellite on 23 March 1966. The count rate for low energy electrons (> 130 Kev) while comparatively high at the maximum is 2 orders of magnitude lower at apogee. 23 March was a day for which the $K_p$ sum was $41_o$ and $K_p$ was > 6 during this entire pass. Here we have a case in which there is a severe depletion of the belt at least from L = 6 to L = 6.6.

A plot of 2 integral modes taken at or near apogee vs. time for a 3 month period is presented in Figure 7. The middle curve is > 130 Kev and bottom curve > 700 Kev. The ordinate of the upper curve (which is plotted on a linear scale) is the daily sum of the Fredericksburg K index. There is not a data point for every day and in fact there are some periods when the data is missing for several days. These missing periods do not indicate satellite failure but rather periods when ground stations were otherwise occupied. Data coverage was approximately one pass per day for the first month. In this region it is apparent that there exists some degree of correlation between the K's and the count rate with some indication of a delay in the 700 Kev peak.

Integral spectra taken at various L values near the magnetic equator i.e. L = 3, 4, 5, 6 on a particular day (10 February 1966) are displayed in Figure 8. These are taken from the 22 minute averages so that the spread in L may be as much as 0.5 earth radius. These curves have not been corrected for pitch angle which would alter the relative values between curves slightly but should not affect the spectral shape. At L = 3 the shape is not exponential but more nearly power law with exponent $\sim$ -2. At L = 4 the characteristic energy $E_o$ is approximately 620 Kev. At L = 5, $E_o$ is approximately 490 Kev and at L = 6, $E_o$ is approximately 285 Kev.

Energy spectra taken at approximately L = 5 but on different days are shown in Figure 9. The numbers at the left are $K_p$ sums for the day before the measurements. There is an apparent enhancement of the 130 Kev electrons at high $K_p$.

An indication of the correlation between the 130 Kev measurements taken when the 22 minute average was maximum during a pass is given by Figure 10. The $K_p$ sums are 2 day sums including the day of the measurements and the previous day. The correlation coefficient for this data is $\delta = 0.861$. Figure 11 is a similar scatter diagram for the 700 Kev measurements, except that the $K_p$ sums are 3 day sums <u>not</u> including the day of the measurement but rather the 3 previous days. The correlation coefficient for this case is $\delta = 0.676$.

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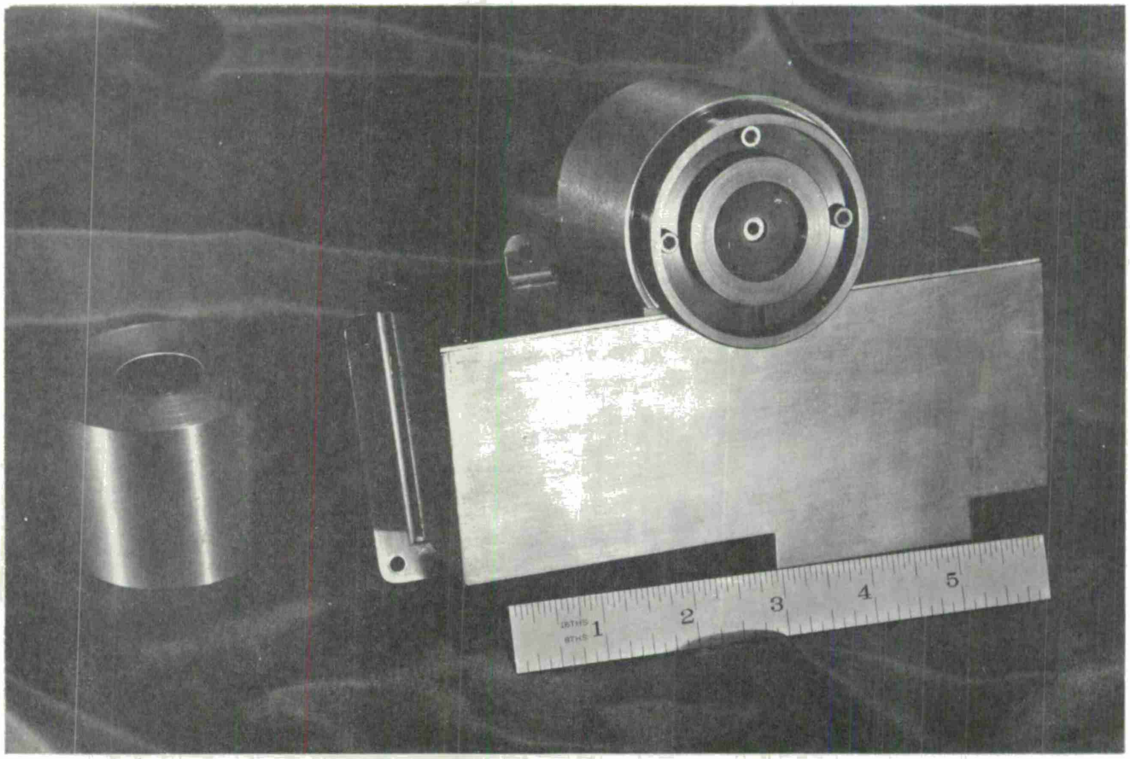


Fig. 1. Radiation experiment package.

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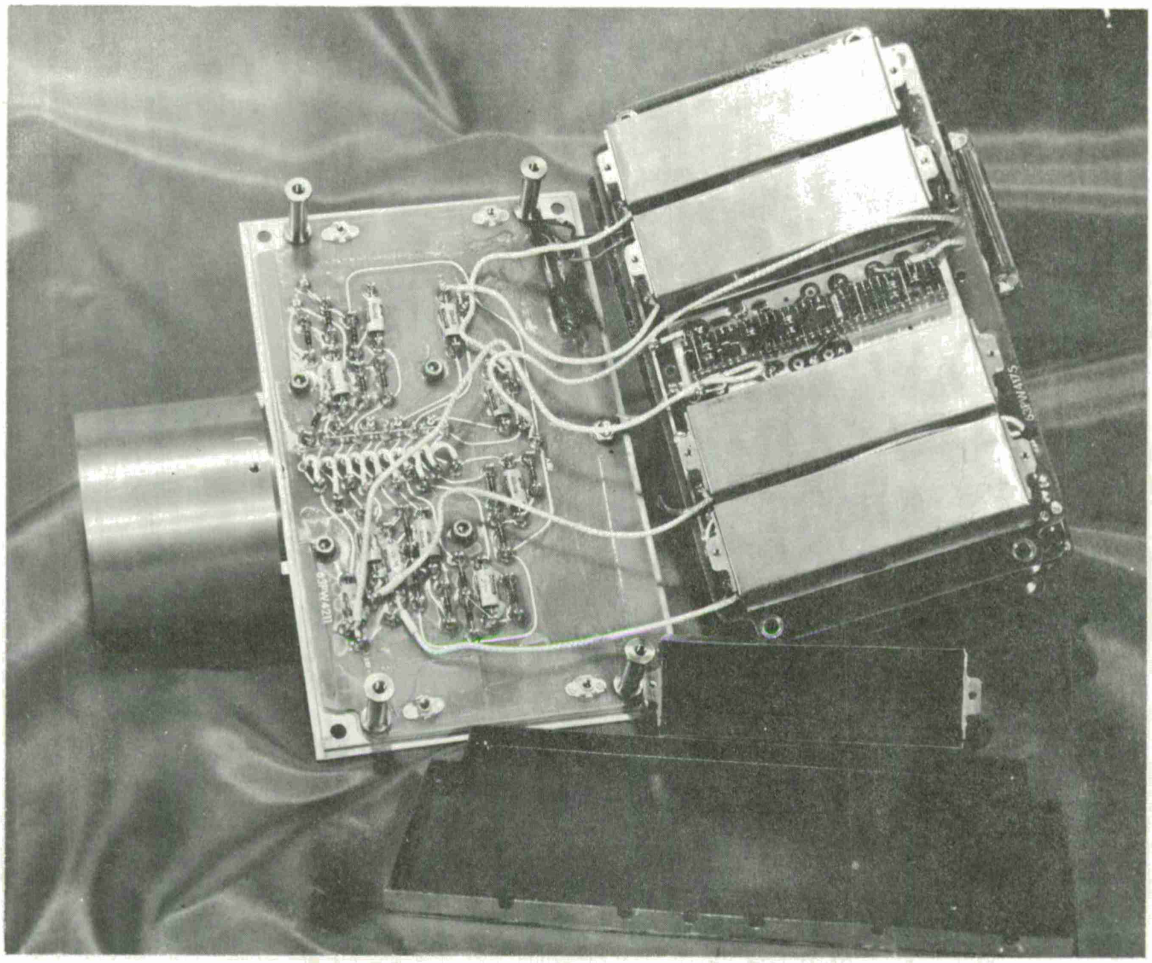


Fig. 2. Radiation experiment electronics.

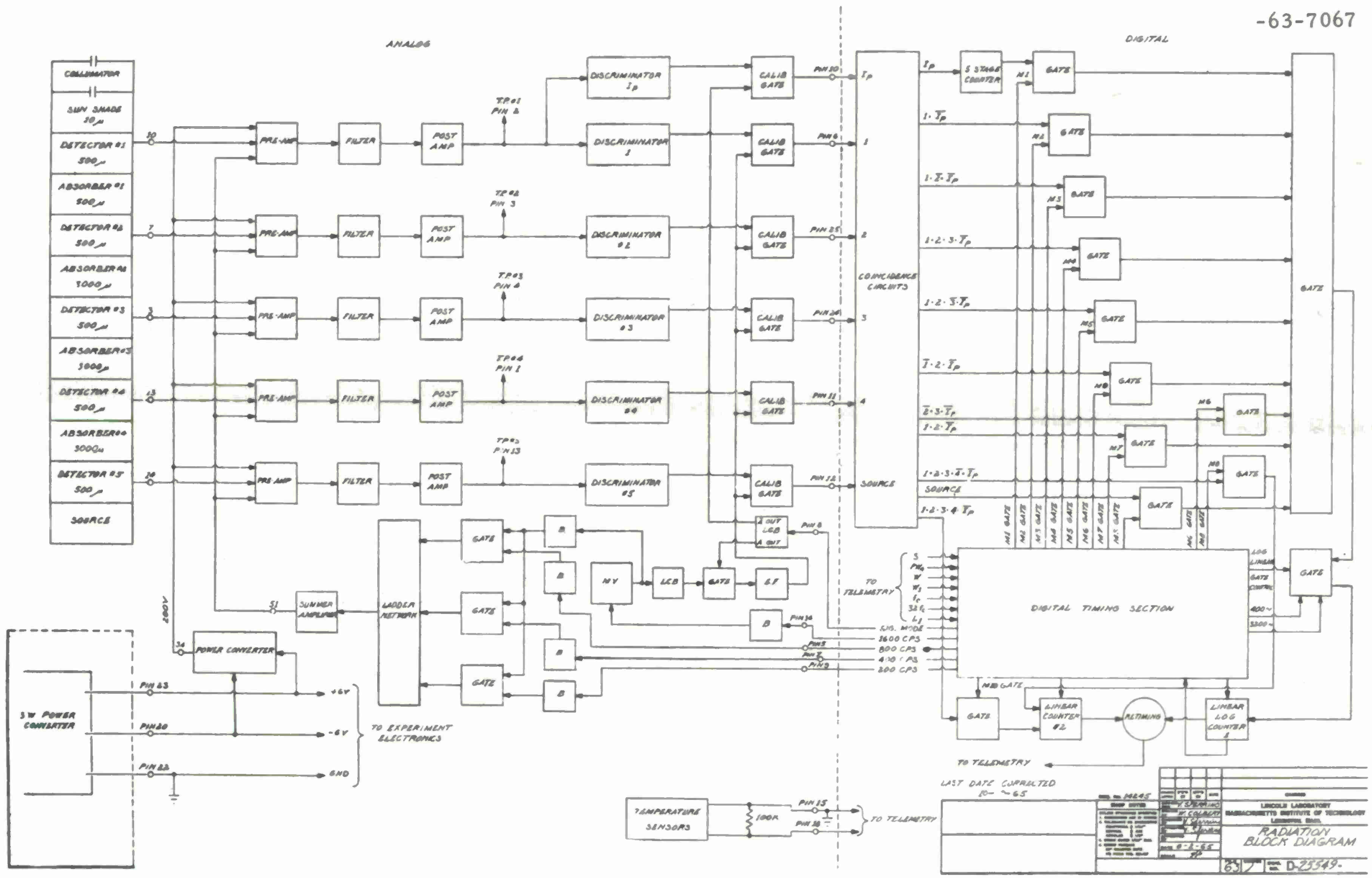



Fig. 3. Radiation experiment block diagram.

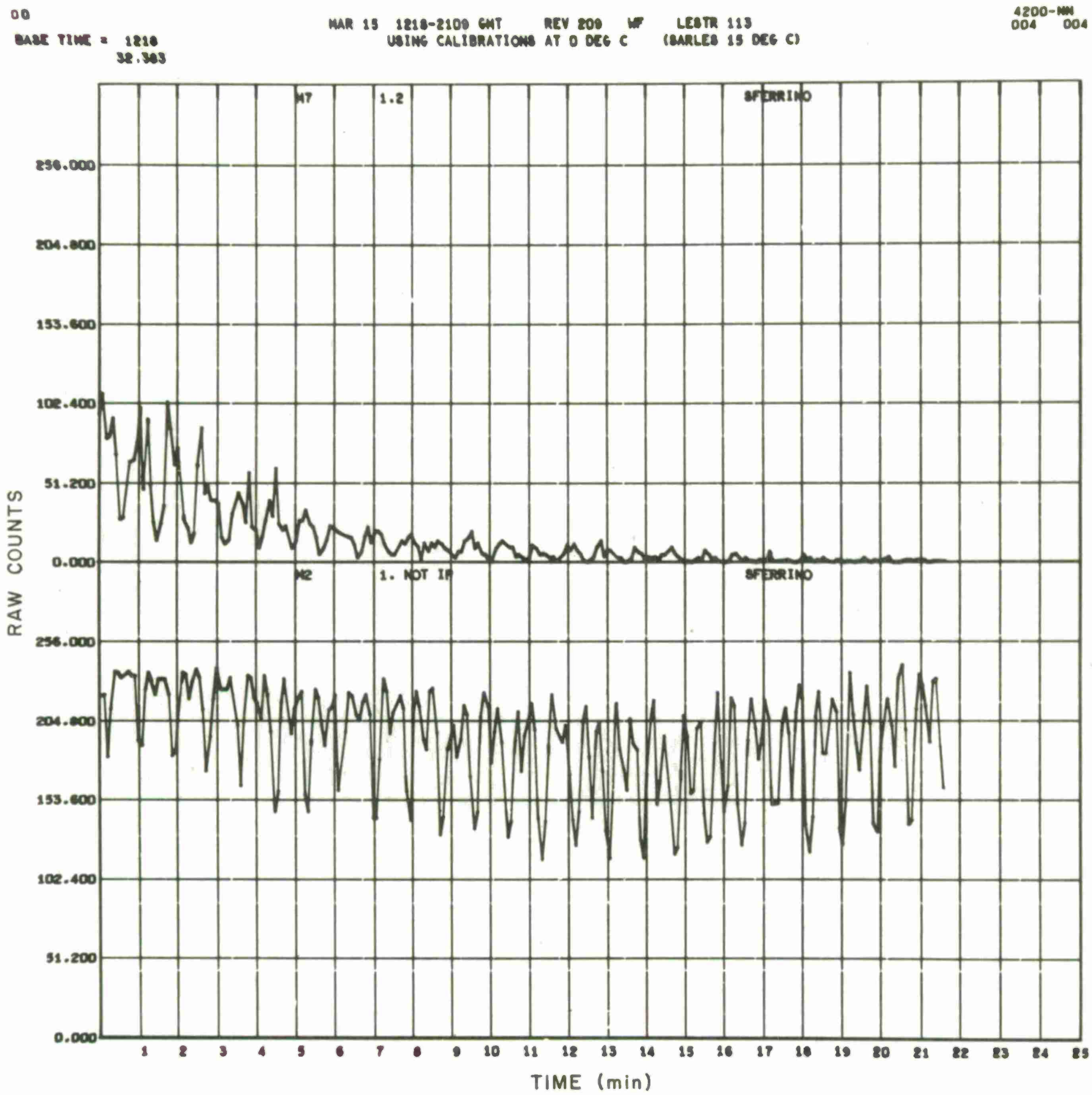



Fig. 4. Raw data computer printout March 15, 1966.

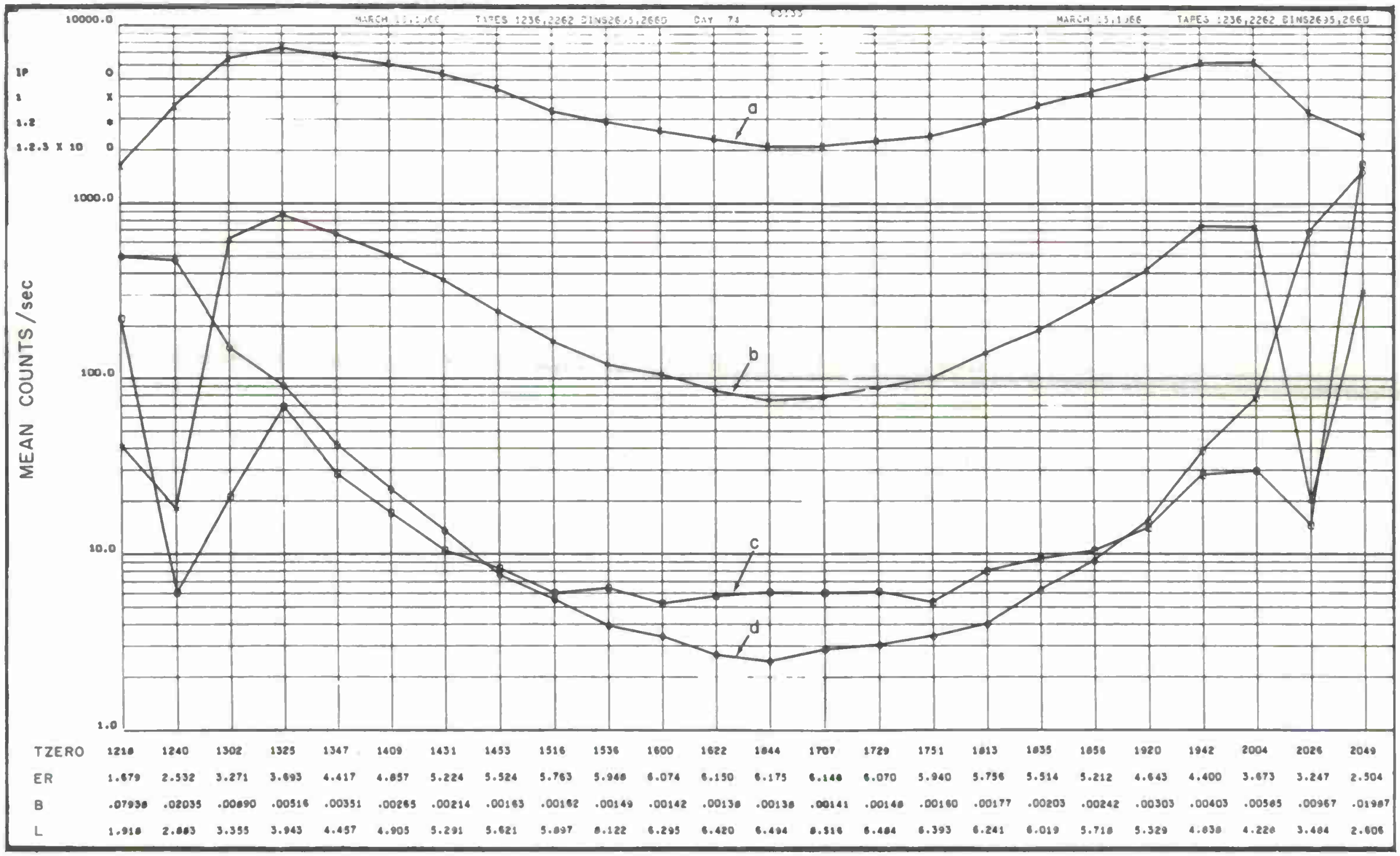
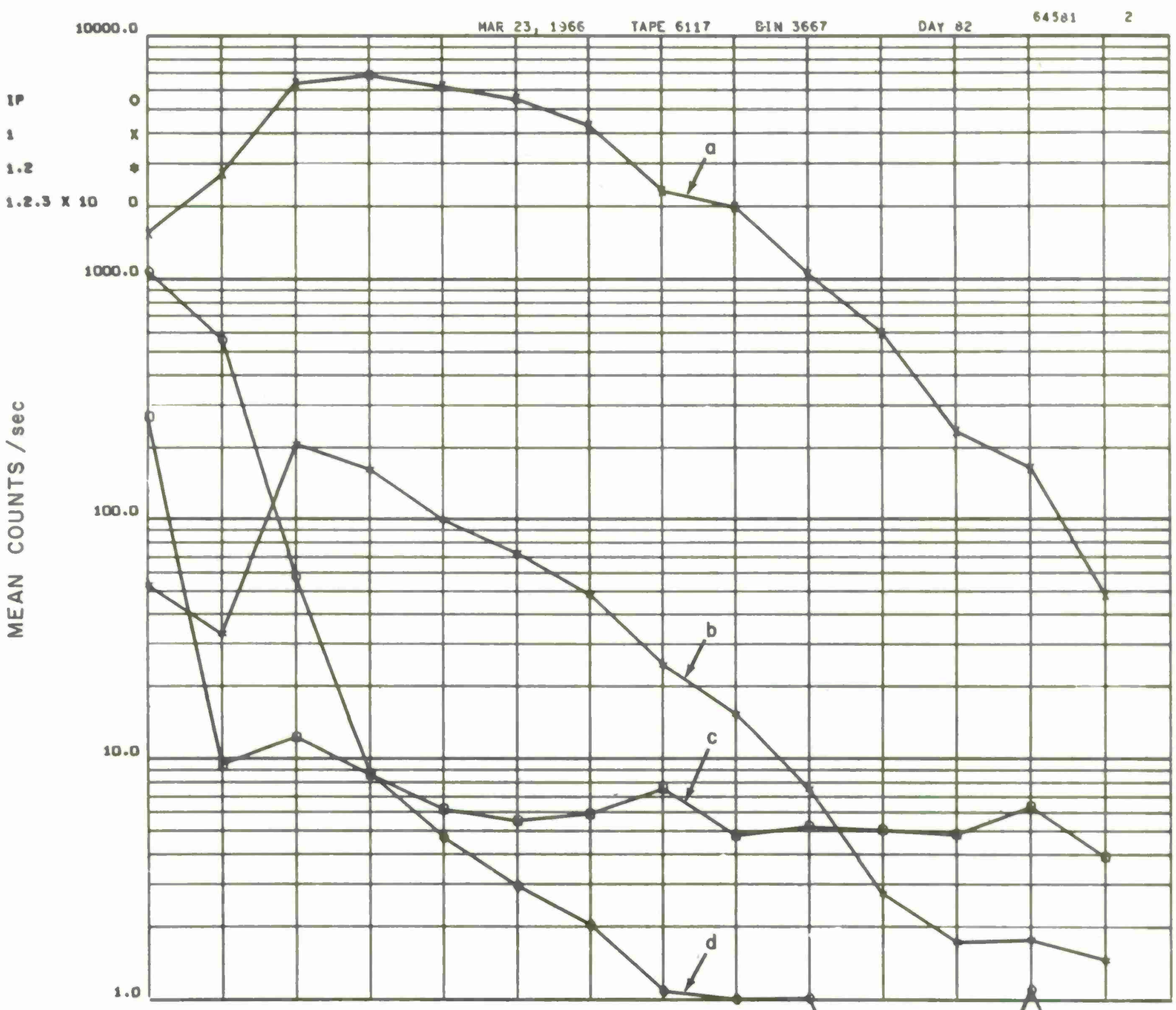



Fig. 5. Integral energy count rates -22 minute averages - 15 March 1966. (a) 130 Kev, (b) 700 Kev, (c) 2.5 Mev, (d) Protons

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TZERO | 1305 | 1327 | 1350 | 1412 | 1434 | 1456 | 1519 | 1541 | 1603 | 1625 | 1647 | 1710 | 1732 | 1754 |
| ER | 2.046 | 2.858 | 3.546 | 4.124 | 4.611 | 5.019 | 5.356 | 5.630 | 5.844 | 6.003 | 6.109 | 6.162 | 6.164 | 6.115 |
| B | .03930 | .01346 | .00690 | .00437 | .00315 | .00247 | .00205 | .00179 | .00162 | .00151 | .00145 | [illegible] | .00145 | .00150 |
| L | 2.130 | 2.891 | 3.563 | 4.151 | 4.665 | 5.112 | 5.498 | 5.828 | 6.103 | 6.326 | 6.497 | [illegible] | 6.678 | 6.686 |

Fig. 6. Integral energy count rates 23 March 1966.

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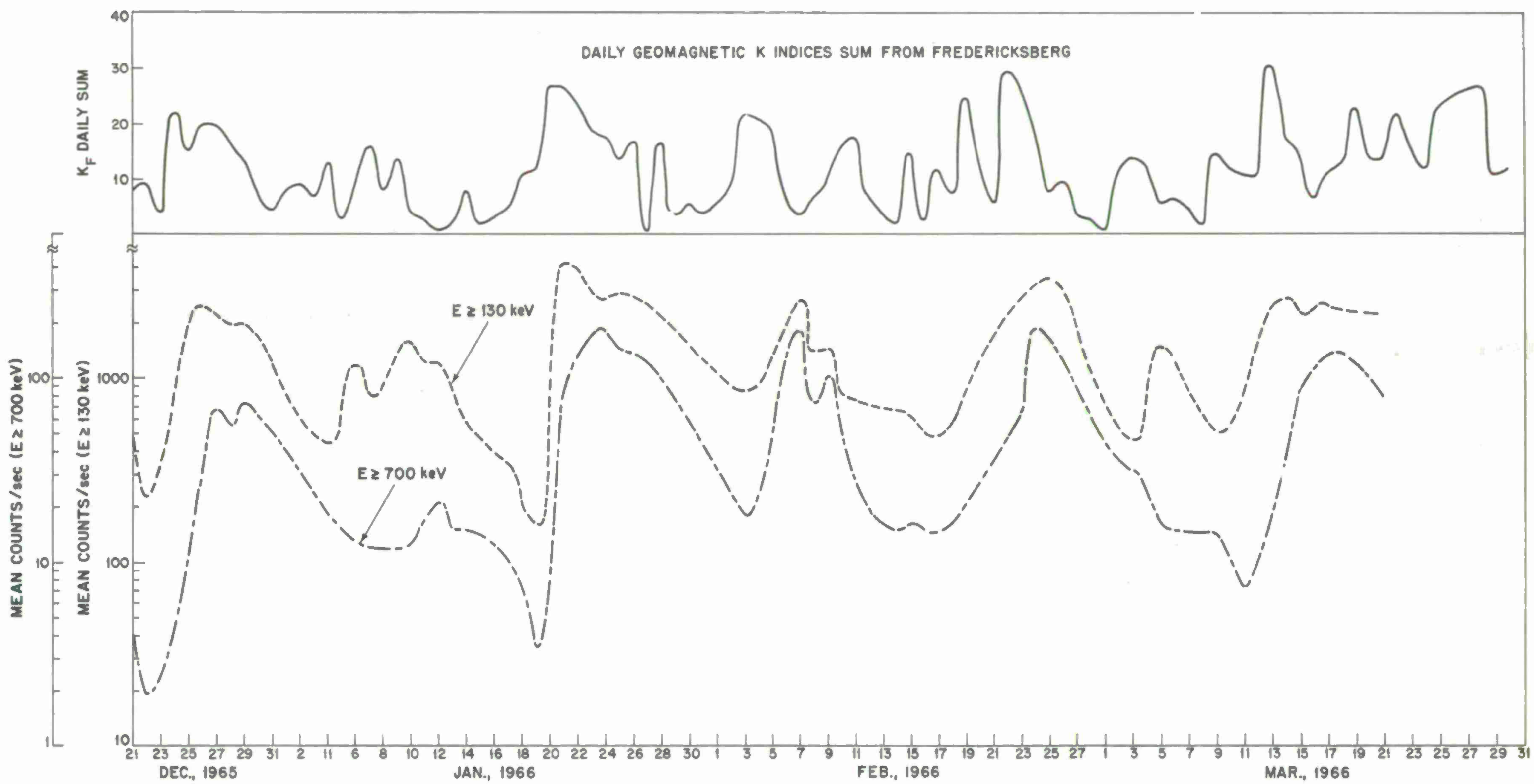


Fig. 7. Comparison of low energy data near apogee with K index.

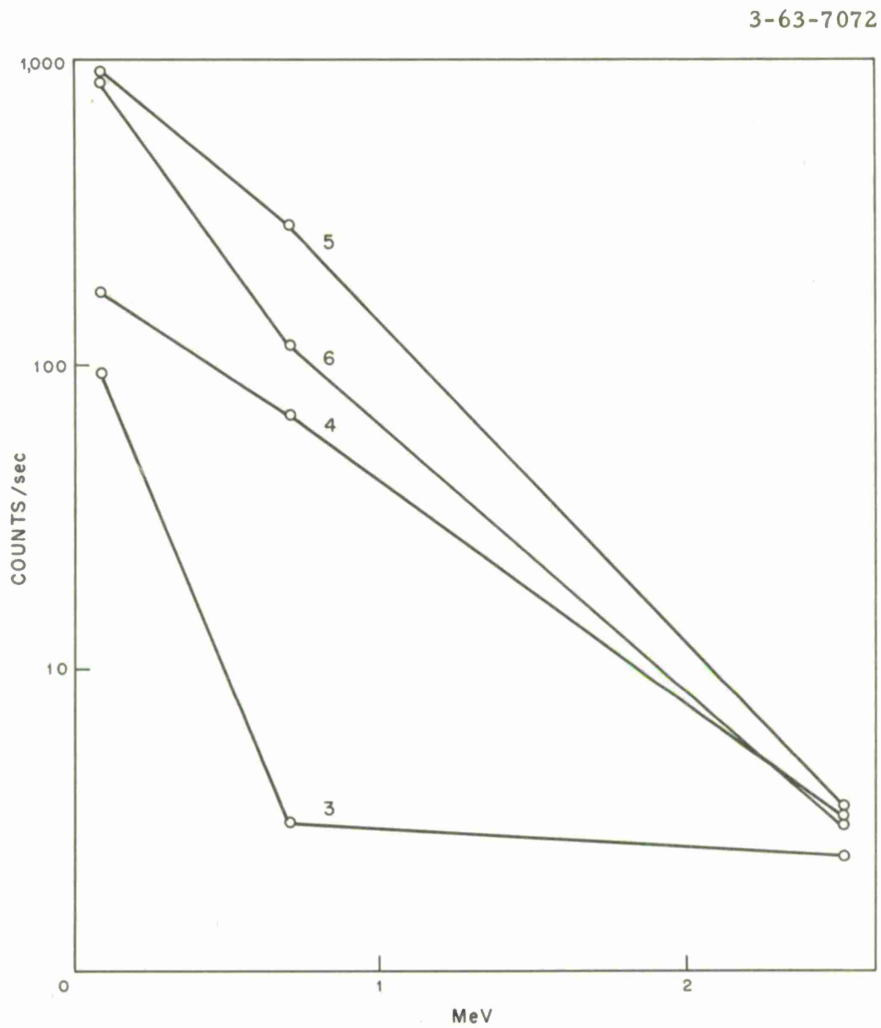


Fig. 8. Integral energy spectra for various L values 10 February 1966.

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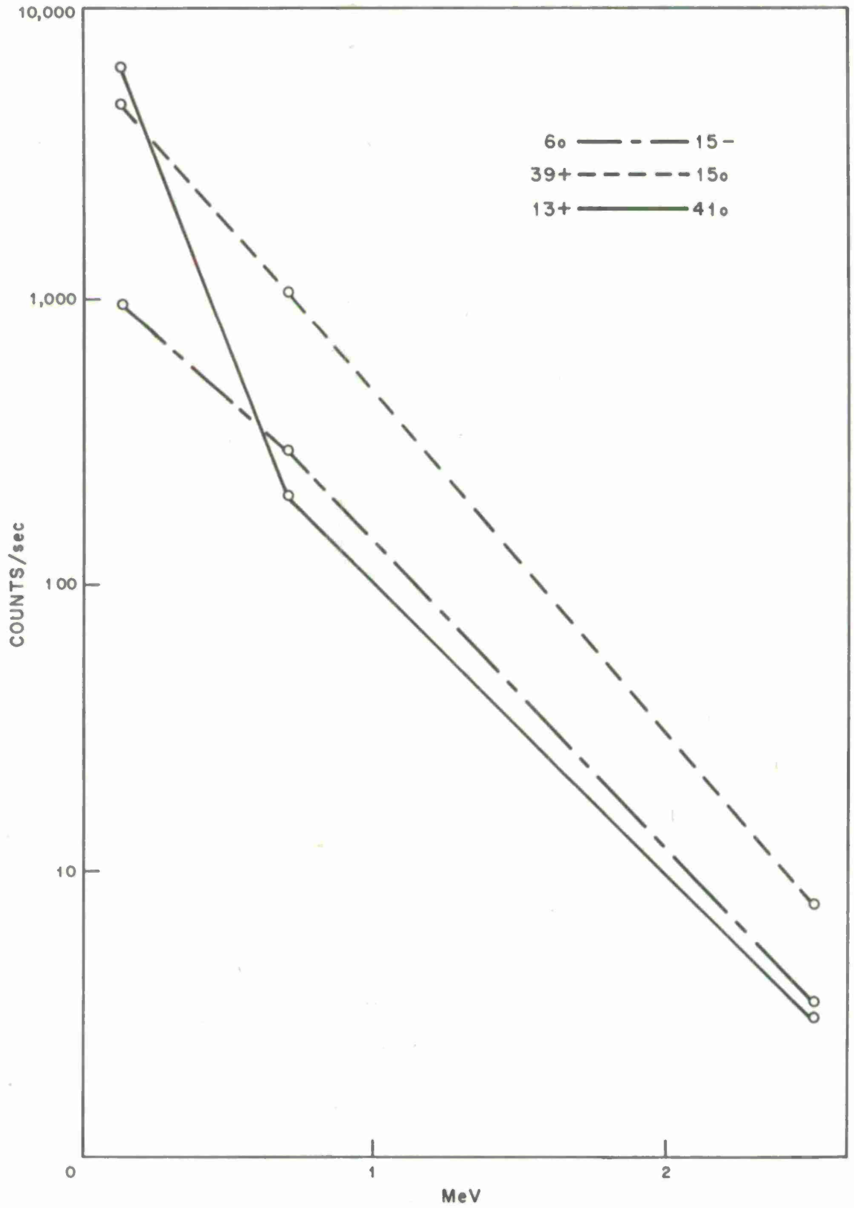


Fig. 9. Integral energy spectra for L = 5 on 3 days with markedly different geomagnetic activity.

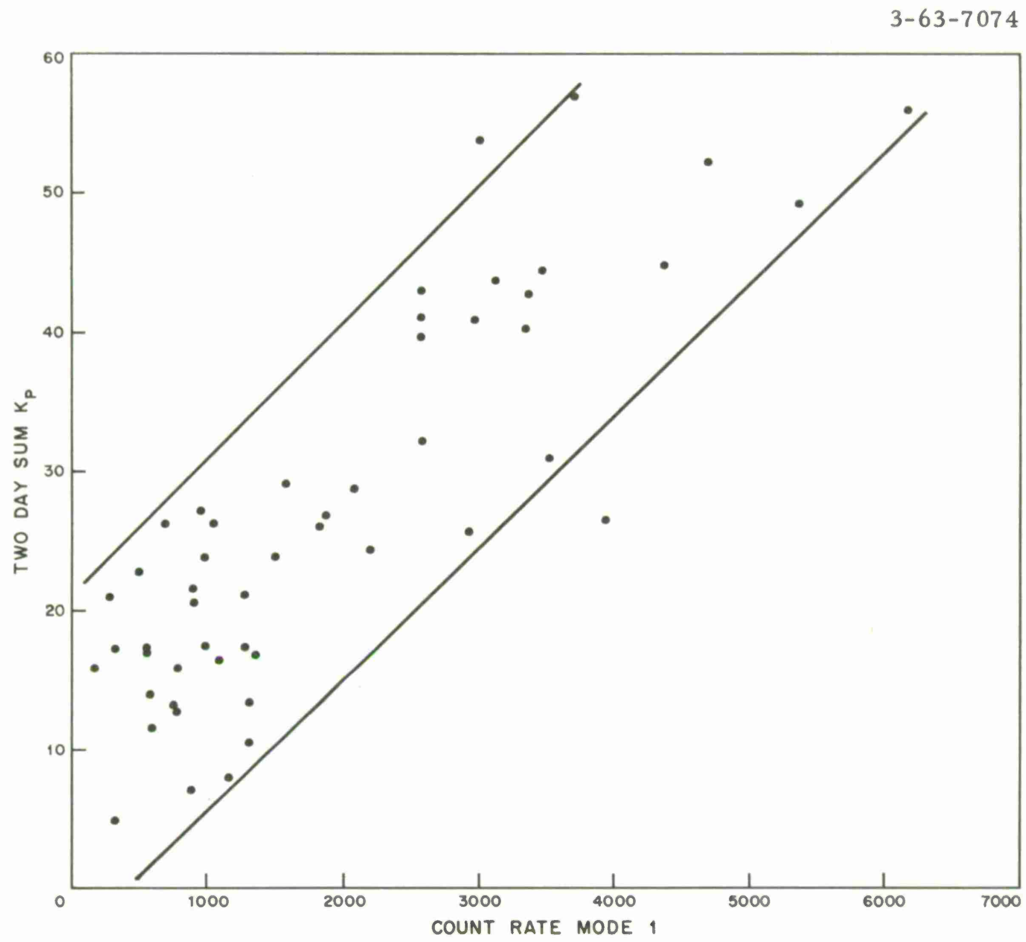


Fig. 10. Correlation of 130 Kev count rates with 2 day $K_p$ sums.

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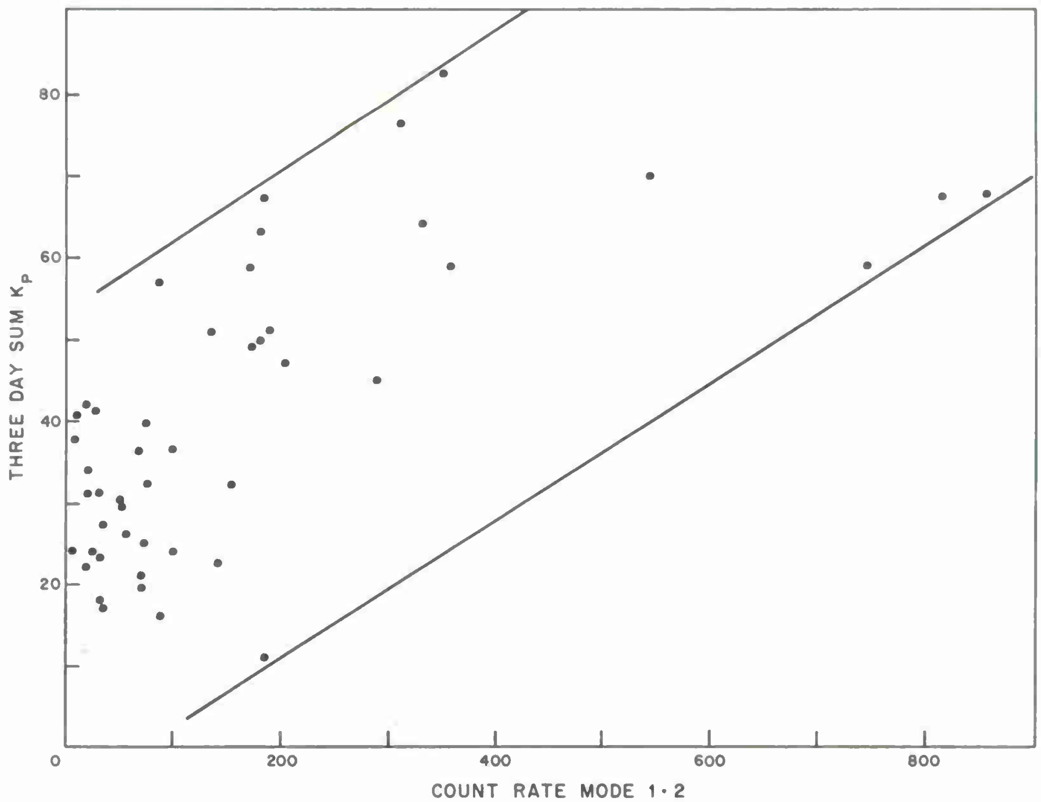


Fig. 11. Correlation of 700 Kev count rates with 3 day $K_p$ sums.

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13. ABSTRACT

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